

## Article

# Implementation of Circular Economy Principles in Regional Solid Municipal Waste Management: The Case of Sverdlovskaya Oblast (Russian Federation)

Iuliia Plastinina \*, Lyudmila Teslyuk, Nataliya Dukmasova and Elena Pikalova

Department of Environmental Economics, Ural Federal University, Mira str., 19, 620002 Ekaterinburg, Russia; tlm.eoxp@mail.ru (L.T.); dykmas-natali@mail.ru (N.D.); e.iu.pikalova@urfu.ru (E.P.)

\* Correspondence: j.plastinina@yandex.ru; Tel.: +7-902-587-1638

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**Abstract:** The circular economy entails the principles of rational waste management to the best advantage. Waste management in the Russian Federation is currently in a reform process, thus it is crucial to choose now the most efficient way for its development. Besides, in addition to general government strategic aims in such a vast country such as Russia, it is very important to take into consideration specific aspects typical of its territories, which will allow determining regional areas of activities. The article analyzes current municipal solid waste management in the Russian Federation. The case study is of one of the regions (Sverdlovskaya Oblast) characterized by some typical and specific problems which illustrate the results of the first stage of reforming. The authors analyzed the existing and planned mechanisms of state regulation in the waste management sector at regional and federal levels, and scrutinized changes in legislation. The development level of the circular economy in the region was determined on the basis of the index method. The life cycle analysis (LCA)-based evaluation approach made it possible to evaluate the economic efficiency of the production and economic activities at different stages of municipal solid waste (waste paper) recycling with due regard to externalities. The research showed that despite the current substantial economic potential of the secondary resources' (waste paper) reuse, there was a low level of development of the circular economy index. Regional factors hindering and fostering the circular economy development were identified. Recommendations for improving the quality of governance of the municipal solid waste management were formulated.

**Keywords:** circular economy; municipal solid waste; regional waste management; Russia; economic efficiency

## 1. Introduction

The circular economy (CE) is an evolutionary stage of the economic activity of modern civilization. Originally, as environmental economist David W. Pearce [1] understood it, the circular economy suggested an economic growth that would lead to a decrease in all types of pollution and in the rate of depletion of non-renewable resources provided that renewable resources are used rationally. Current circular economy evolves a complex approach to economic activities, i.e., multiple uses of material resources achieved through implementation of respective technological and organizational innovations of production processes and waste management schemes [2]. Such an approach leads to a significant reduction of virgin raw material consumption, increase in the use of renewable resources, reduction of the need for landfill space, and improvement of the environmental quality.

With further development of industrial production and growth of public consumption, Russia, just as the rest of the world, faces increasing environmental and economic problems. Therefore, business and government are interested in developing and implementing business models that are typical of the CE and are being successfully developed and applied worldwide for several decades. Currently in Russia, there is quite a limited number of authors covering issues of CE development and taking Russian experience as an example. With the growing interest in the implementation of the circular economy, Russia absorbs the international experience acquired in this field, primarily in the area of scientific research.

The aim of this article is to identify the main problems and obstacles that prevent CE development in respect to optimal waste management systems. For this, the following specific objectives have been pursued. First, to assess the current level of the CE development in Russia and the prospects for further development in accordance with the ongoing state reform in the field of waste management. Secondly, to determine the criteria for the appeal of the activities in this sphere for business, both for manufacturers of products from secondary resources, and for the companies engaged in raw material supply (separate waste collection, sorting, etc.). Finally, to analyze the instruments of governance of the municipal solid waste (MSW) management used to create favorable conditions for the transition to a circular economy.

The objectives pursued in this article are addressed through the analysis of the dynamics of production and recycling of MSW nationwide and in Sverdlovskaya Oblast (chosen as an example), the legislation of the Russian Federation in connection with the ongoing reform in this area, as well as the efficiency of economic activity in a closed loop. The level of CE development in the region was assessed through an index method. A life cycle analysis (LCA)-based evaluation approach was applied to determine the economic efficiency of CE implementation through the example of waste paper recycling with regard to direct costs and co-benefits obtained due to the presence of positive externalities [3].

## 2. Theoretical Framing of Research

### 2.1. Circular Approach in the Global Economy

Existing research literature gives three main characteristics to a circular economy: first, enhanced monitoring of natural resources and adherence to a sustainable balance of renewable resources to preserve and maintain the inexhaustible level of natural capital; secondly, optimization of consumption processes through the development and distribution of products, components, and materials that meet the highest level of their reuse; finally, the identification and prevention of adverse externalities of current production activities with the aim of improving the efficiency of economic and ecological systems.

Early schools of thought started to give a theoretical basis to the necessity of a transition from the linear economy to another type of economic model in the 1960s [4,5], when it became clear that non-monetary factors should be taken into account. A new school started to form within the framework of environmental economics that was giving ground for the idea of sustainable growth, namely a circular or closed economy [6,7]. The 21st century began with a conceptually new experience of implementation of the circular economy at the level of individual businesses [8,9] and at the country level, first of all, in the countries with advanced economies, such as Japan, the Netherlands, Germany, Austria, and the UK [10,11].

Originally, quite a number of theoretical and practical papers describing the circular economy were devoted to the justification of the perspectives of the use of recycled materials. It was found that while the first and the simplest variants of recovery have apparent advantages, further benefits gradually become increasingly challenging [3,12,13]. It was determined that at a certain stage, recycling becomes inefficient. Otherwise stated, the contemporary level of technological development demonstrates that resources cannot be used an unlimited number of times. Research in science and technology aimed at the extension of the resource life cycle remains an urgent challenge [14–16].

Justifying economic efficiency of material resources recycling in economic activities is also another important research trend. Under market economy conditions, recycling can win recognition and gain widespread use in cases of interest from the private sector, i.e., in cases of its economic feasibility. Such an assessment has required the development of a specific approach to cost accounting, such as a cost–benefit analysis of the economic activities only on the basis of direct costs, which in this particular situation is misleading. Full analysis is feasible with due regard to external factors, most notably, ecological component represented by resource depletion and environmental damage. Thus, consideration of external factors is required for internalization of environmental costs in the economic system. In the long run, economic activities must follow a business model demonstrating high efficiency with low material, energy, and environmental costs [10]. As one of the internalization tools, it was proposed to use environmental taxes and fees being equivalents of external expenses which can help form market prices with due regard to the environmental impact of the economic activity [17].

At this stage in the development of the CE theoretical base, the formulation of analytical approaches is of special interest, including approaches aimed at optimization of material flows and waste recovery, development of index approaches, etc. [18–20]. Following the 2008/98/CE Directive on Municipal Solid Waste, advanced technologies started to be developed and introduced to generate energy from waste, i.e., waste incineration with subsequent heat recovery and simultaneous reduction of harmful emissions under certain conditions of the thermal process [21]. The construction of such facilities in Russia has only recently become feasible. The sociocultural aspect of CE is of increasing interest [22,23]. The principles of reduced waste accumulation and increased recycling volumes have been implemented in countries with advanced economies for almost three decades [24]. Despite the experience obtained, no versatile approach to manage wastes (including municipal waste) exists to satisfy any country. When choosing a waste management strategy for a particular country, the key factors can include the level of the development of its economy, social factors, and its size [25,26]. International support can also play an important role in the implementation of the circular economy principles [27].

Waste management strategies have different cost depending on the complexity of recycling and economic development of the region (See Table 1).

**Table 1.** Cost of municipal solid waste (MSW) management services against the income level of the country (2012), US dollar/t [28].

Service	Low-Income Country	Lower-Middle-Income Country	Upper-Middle-Income Country	High-Income Country
Collection, loading, and transportation	20–50	30–75	40–90	85–250
Disposal at disposal facilities	10–30	15–40	25–65	40–100
Storage at waste landfills	2–8	3–10	–	–
Composting	5–30	10–40	20–75	35–90
Waste-to-energy incineration	–	40–100	60–150	70–200
Anaerobic fermentation	–	20–80	50–100	65–150
Waste recycling	–	120–180	150–210	220–310

Waste burial and waste storage at landfills and disposal facilities is apparently cheaper in the linear model. Yet, waste recycling potentially gives benefits due to:

- Reduction of direct costs when producing items from the secondary raw materials.

- Reduction of waste burial expenses (incineration or storage at landfills).
- Reduction in the requirement of virgin raw materials.

Consideration of the co-benefits makes it possible to adjust expenditures and to obtain an expanded vision of actual efficiency of the economic activities using secondary raw materials as production factor [28].

## 2.2. Circular Economy in Russia

The total area of the Russian Federation is 17,125.2 thousand km<sup>2</sup>. The Russian Federation consists of 85 territorial entities, united in eight federal districts. As of 2019, the population is 146.8 million people with an average density of 8.6 people per 1 km<sup>2</sup> (from 60.5 people per 1 km<sup>2</sup> in the Central Federal District to 1.0 people per 1 km<sup>2</sup> in the Far Eastern Federal District). The share of the urban population on average across Russia is 74%.

According to the State Report “Concerning the State and Environmental Protection of the Russian Federation in 2017”, waste production and consumption have increased (See Table 2): for the period from 2013 to 2017 the annual waste generation increased by more than 17%.

**Table 2.** Dynamics of generation of production and consumer wastes in the Russian Federation, 2013–2017 [29].

Year	Generation of Production and Consumer Wastes, mln t	MSW Generation, mln m <sup>3</sup> /mln t	Production and Consumer Waste Recovery and Neutralization, mln t/% of Total Waste Generated
2013	5153	260.9/ 55.6	2043.6/39.7
2014	5268	262.8/55.9	2357.2/44.7
2015	5060	266.5/56.8	2685.1/53.0
2016	5441	268.8/57.2	3243.7/59.6
2017	6221	274.4/58.4	3264.5/52.5

In 2017, 6220.6 million tons of waste were generated within the territory of the Russian Federation, including 58.4 million tons (0.88%) of MSW, 398 kg per capita. The amount of production and consumer waste recovered within this period was 52.5% of the total amount of waste generated, mainly due to industrial waste. The share of recycled MSW in the Russian Federation was about 10%. Burial is the main method of the MSW management in the Russian Federation. The MSW collection in cities is mainly carried out by the mixed container method without prior sorting. In 2017, the volume of the MSW removed to burial facilities amounted to 239 mln m<sup>3</sup> (50.9 mln t) or 87% of the total MSW removal; to waste sorting plants 27.4 mln m<sup>3</sup> (5.8 million t) or 10%; for neutralization, including removal to waste incineration plants—6.0 mln m<sup>3</sup> (0.9 mln t) or 2%. According to Greenpeace [30], Russia has more than 14 thousand large waste landfills with a total area of more than 4 mln ha that increases annually by 0.4 mln ha, which corresponds to the territories of Moscow and St. Petersburg, combined.

In Russia, the CE model is still in the process of its implementation [31–34], though partial introduction of its principles began during the Soviet days, in the period of state-controlled economy. In the USSR, collection and recycling of such secondary raw materials as wastepaper, scrap-metal, and glass were widely used. These materials were collected by everyone, from school students to pensioners. Today, state centralized collection does not exist in the residential sector, though its functions are partially performed by certain business entities whose activities are governed by market demands and cannot be considered regular. The volume of the waste paper collection increases primarily due to the demand from foreign paper manufacturers. Expenses for plastic waste recycling are not high, thus Russian manufacturers enthusiastically buy it stimulating polymer waste collection. Scrap metal has always been appreciated by industrial enterprises, therefore companies that collected it are the only ones among waste collectors that have never stopped their activity since the USSR days. There is practically no commercial glass waste collection.

Thus, municipal waste and equal-status waste from the enterprises (offices, shops, entities, etc.) is collected more or less intensively only in those spheres which are of interest for the manufacturers (See Table 3) [35]. Besides, the complex approach has been lost. This approach is necessary for successful operation of the system, and it ensures undisturbed operation of all members, starting from waste collection and treatment to the recycling process for the secondary raw materials and product release schemes with its further recovery. It is necessary to re-establish the waste collection system and to ensure that there is legal framework applied to it and that it is supported by the state.

Today, waste management in Russia is in a reform process, therefore Soviet and foreign experience gained in this sphere can be successfully used with due regard to the specifics of the current situation in Russia and in accordance with the level of the social and economic development of the Russian regions.

### 2.3. Integrated Strategy to Manage Municipal Solid Waste in the Russian Federation

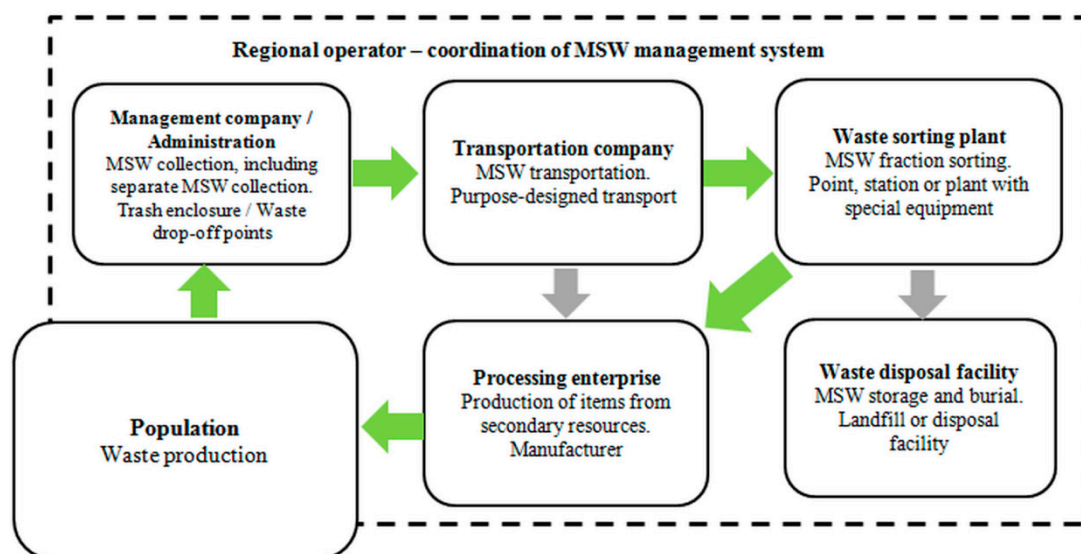
An integrated strategy to manage MSW in the Russian Federation was elaborated in 2013 [36]. It envisages the increase in recovery volumes of the secondary material resources up to 60%. The new legal requirements (Government Executive Order No.1589-p, 2017) state that the disposal facilities must not accept those wastes that can be recovered (182 types totally). Besides, the following amendments were introduced in the laws: transfer of control from the municipal level to the regional one; introduction of manufacturer's liability for waste recovery and its safe placement; establishment of standards for waste recycling, etc. It is planned to delegate authority to control MSW management to regional operators starting from January 2019. Being commercial entities, they will gain income from rendering services to the population. As this takes place, a part of this income will be transferred to subcontractors, namely companies that are directly responsible for waste management.

**Table 3.** Key market indicators for certain types of waste in 2017 (th t) [35].

Type of Raw Material	Waste Paper	Glass	Plastic Material	Rubber Waste
Resource base	Paper waste	Packaging, sheet glass, other types of glass	All types of plastic materials, including packaging	Tires, outer casing of a tire, car-tire inner tube
Generation of recyclable raw materials *	12,000	4000	3600	729
Collection	3230	1130	450	95
Recycling share	27%	28%	12%	13%
Production of secondary raw materials	3230	1130	450	66
Export	349	0.2	12	0.5
Import	34	62.7	23	10.4
Estimated consumption in the domestic market	2915	1193	461	76.2

\* Consumer waste of commercial enterprises and residential areas, production waste that entered the market (recycling at own facilities was not taken into account).

According to the reform, MSW management system will comprise several stages of waste movement which finally must form a closed loop (See Figure 1).



**Figure 1.** Closed loop for MSW management in the Russian Federation: members and their functions.

Thus, following the reform, significant changes will occur, first of all, at the level of regions that differ both in volume and morphological composition of the waste. The differences reflect the social and economic indicators, regional specifics, structure, and the focus of economic activities, etc. To achieve the targets envisaged in the Integrated Strategy of the Russian Federation, regional schemes are being developed for the production and consumer waste management. Their elaboration is based on the requirements set forth in the main legal acts, such as Federal Law No. 89-Φ3 Concerning Production and Consumer Wastes and Federal Law No. 7-Φ3 Concerning Environmental Protection.

The case study of a large industrial Russian region, Sverdlovskaya Oblast, the Ural Federal District, illustrates the efficiency of the implementation of the CE principles.

### 3. Materials and Methods

#### 3.1. Waste Management in Sverdlovskaya Oblast

In many socio-economic development indicators, Sverdlovskaya Oblast is among the ten top-ranking regions of the Russian Federation. As of 2019, the total population of Sverdlovskaya Oblast is 4315.7 thousand people. The average population density in the region is 22.3 people per 1 km<sup>2</sup>. The share of urban population is approaching 85%.

Sverdlovskaya Oblast annually produces about 1.7 mln tons of MSW, 328 kg per capita; the volume of their recycling (recovery and neutralization) is about 15.5% (See Table 4). Neutralization occurs primarily by burning without heat recovery. The total mass of waste accumulated in the region currently amounts to almost 60 mln tons.

**Table 4.** MSW production and use in Sverdlovskaya Oblast [37].

Year	Produced, Thousand Tons	Recovered and Neutralized, Thousand Tons/%	Placed, Thousand Tons/%
2013	1827.1	404.6/22.14	1442.8/78.9
2014	1540.2	198.9/12.9	1289.7/83.7
2015	1523.6	216.1/14.18	1250.1/82.0
2016	1409.3	177.7/12.6	1289.6/91.5
2017	1414.0	155.9/11.0	1204.4/85.17

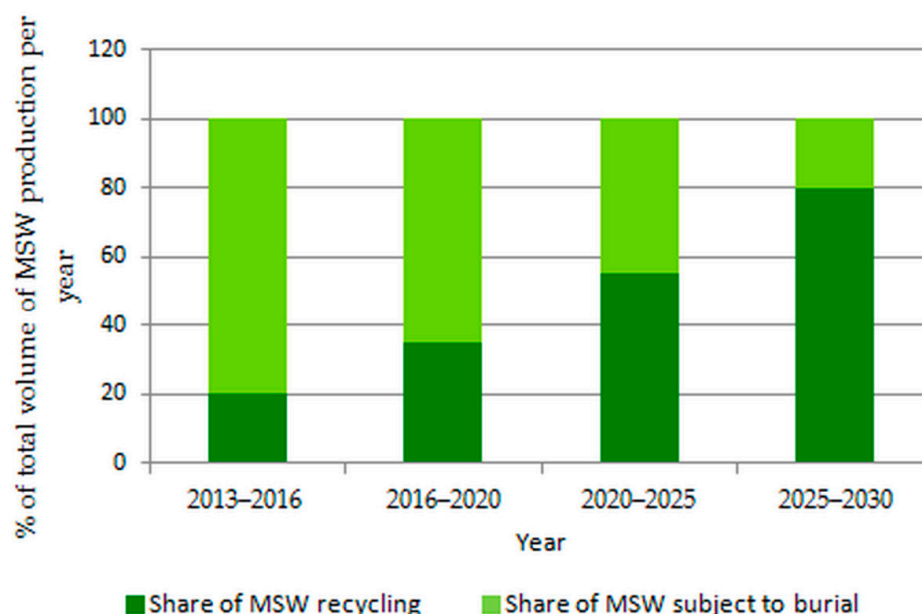
Forty-nine processing companies (with exception of scrap metal) are registered in Sverdlovskaya Oblast with total area of 194,307 km<sup>2</sup>, 47 cities and towns, and approximately 2000 rural communities.



These companies are mostly located in several cities and towns like Yekaterinburg, Pervouralsk, Nizhny Tagil, Asbest, Verkhnyaya Pyshma. As the Ural region is an industrial zone, there are 270 processing companies that process ferrous and non-ferrous metals. Regional processing enterprises mostly treat (collect, sort, and prepare) secondary raw materials, most parts of which are then taken to Permsky Kray, Chelyabinskaya Oblast, and other regions.

There are hardly any waste sorting plants in the region. In 2011, the only waste sorting plant with the capacity of up to 200 thousand tons per year was launched in Yekaterinburg, which had to ensure recovery of 27 types of secondary resources in the volume equal to about 36% of total MSW produced by the city population. Yet due to certain factors, less than 2% of valuable components were recovered in 2012 and 2013. The main part of MSW (more than 85%) is placed at the landfills or disposal facilities, most of which are not able to follow state requirements pertaining to sanitary and environmental safety. For example, as per data from the Ministry of Natural Resources and Environmental Protection for Sverdlovskaya Oblast, 69% of MSW disposal facilities out of 456 facilities registered as of the beginning of 2013 do not have any formalized documents for land use, and 88% do not have all relevant design estimate documentation. The insignificant recycling volume is attributed to the lack of waste source separation (which was planned to be launched in the region in January 2019), lack of required infrastructure, and insufficient number of processing companies.

Management of separate waste collection illustrates the formality of this approach. Pilot projects for separate waste collection in Yekaterinburg at the district level (2013) failed due to several reasons: additional monitoring was required for the containers already filled with waste to avoid intentional or accidental contamination of the fraction with foreign items; more machines were needed to remove different fractions or authorization was required for sorting enterprises to do it; the number of the containers had to be in agreement with sanitary requirements as the latter limited their number and allowed only five at the same site, while city authorities planned to have much more, etc. Sverdlovskaya Oblast Administration officials indicate that identified managerial challenges and weaknesses had not been eliminated by the launch of the citywide waste separation project in January 2019, which led to the dismissal of this initiative. Yet in accordance with the regional waste management program [38] (See Figure 2), the share of secondary resources recovery within the period from 2013 to 2016 must be equal to at least 20%, with the increase up to 50% by 2020.



**Figure 2.** Some target values of the Integrated Strategy to Manage Wastes, including MSW in Sverdlovskaya Oblast [38].

The article analyzes the efficiency of state management and support in respect to MSW. The attitude of the population and business towards the MSW recovery is evaluated on the basis of a questionnaire and a poll.

The questionnaire was administered among the entrepreneurs engaged in the recycling industry, namely, members of the Ural Federal District Waste Processors Union from 14 companies. The questionnaires were sent via electronic resources and included 10 questions related to the issues of MSW management in the region. The answers detailed description of the situation and recommendations for improving the management process.

The poll was conducted at the Congress called the Industrial Ecology of the Regions, held in 2018 and 2019 in Yekaterinburg. A representative of the Ministry of Natural Resources and Environmental Protection, participants, and attendees of the Congress (27 people totally) were asked about their attitude towards separate waste collection, including waste paper.

### 3.2. Calculation of A Circular Economy Development Index in Sverdlovskaya Oblast

The CE development index evaluation to determine the circular economy development process has recently been in widespread use [20,39–41]. Based on the dynamics of the aggregates, the index approach allows to address the changes in a more comprehensive way. Due to their nature, index approaches are characterized by a certain level of incompleteness in assessing the interrelation of elements and processes occurring in the circular economy. To study the current recycling situation in the context of MSW management in Sverdlovskaya Oblast, the authors chose the Circular Economy Development Index (CEDI), introduced by Pakhomova and Rikhter [19].

The CEDI is based on the Ellen MacArthur Foundation's general theoretical circular economy model [2]. This model assumes that the CE can be developed on the basis of different approaches applied in industry and agriculture with due regard to the development of closed supply chains, namely, maintenance, reuse, recovery, and recycling of the quantifiable volumes of production and wastes for industries, as well as composting, anaerobic fermentation, and production of biochemical raw materials for the agricultural sector. The CEDI method has an undeniable advantage: it allows to evaluate the situation observed at an individual enterprise and the situation typical of the industrial sector in general, which is more expedient for the assessment of the circular efficiency of the waste management.

Regional CEDI calculation was performed with a well-grounded amendment of the recycling volumes. The recycling volumes were adopted as the difference between waste production and waste placement (Table 4, column 2 minus column 4) but not as the recovery and neutralization data given in the state report (Table 4, column 3). Such an amendment was adopted as the term *recycling* used in the methodology, and does not have any legislative definition in Russia, though its use in scientific documents assumes the actions related to the forms of waste management which exclude their final placement, namely, burial, storage or composting.

According to the Russian terminology, waste recovery includes the following:

- Use of wastes for the production of goods.
- Direct reuse of wastes (recycling).
- Their return to the production cycle after appropriate recycling (regeneration).
- Extraction of useful components for their reuse (recuperation).

According to the legislation, waste neutralization is a reduction in the mass of waste, changes in its composition, physical and chemical properties (including incineration and/or decontamination at recovery facilities).

For example, 1414.0 th.t of MSW were produced in Sverdlovskaya Oblast in 2017 and 1204.4 th.t were placed at the landfills, therefore 206.9 th.t were recycled.

The CEDI is calculated as per the formula below (1):

$$\text{CEDI} = (L \cdot i_1 + R \cdot i_2 + M \cdot i_3 + C \cdot i_4) \times 100\%/W \quad (1)$$



where

- L is the volume of products that have undergone technical maintenance (tons or monetary units).
- R is the volume of re-used products (tons or monetary units).
- M is the volume of recovered products (tons or monetary units).
- C is the volume of recycled products and wastes (tons or monetary units).
- i1, i2, i3, and i4 are the weighing factors of the method applied for management of wastes and end-of-life products for industrial sectors.
- W is a total volume of industrial wastes and products taken out of service (tons or monetary units).

Respective management methods and the values of the weighing factors (i) for MSW management are given in Table 5, calculated using the data from References [2,42,43].

**Table 5.** Clarified weighing factors for the methods applied for management of wastes and products taken out of service when evaluating industrial sectors.

Circular Economy Element in the Context of MSW Management	Resource Saving, %	Reduction of CO <sub>2</sub> Emission, %	Cost-Efficiency, %	Total	Weight (i1, 2, 3, 4)
MSW recycling (i1)	90	86	80	256	$i1 = 256/256 = 1$
Composting and anaerobic fermentation (i2)	36	30	55	$\Sigma Kn$	$i2 = 121/256 = 0.47$
Maximum total value				$S_{max} = 256$	

### 3.3. Definition of Economic Efficiency of the Economic Activities through A Circular Economy Principle

All the companies involved in a closed supply chain at different stages of the product life cycle must first of all have an economic interest in their activities and their development.

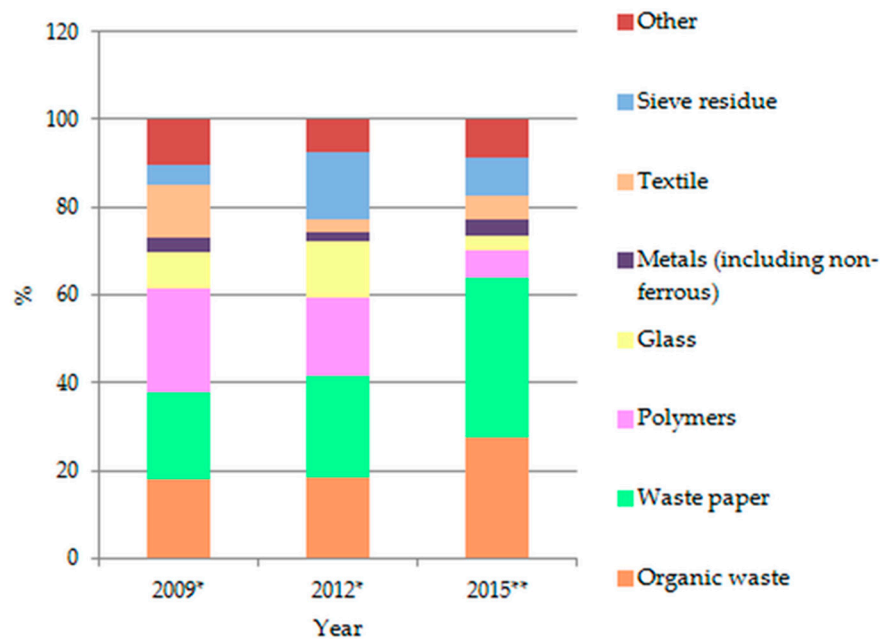
The economic efficiency of implementation of a circular economy in respect of waste management in Sverdlovskaya Oblast was evaluated through the study of collection, preparation, and recycling of waste paper. As per Reference [17], to calculate the externalities arising from waste production and recycling, it is possible to apply an LCA-based evaluation approach.

The following life cycle stages can be identified for paper production: paper production from industrial wood (1); waste production and waste treatment (collection, sorting, preparation of Group A, B, and C raw materials (2); and re-use of the resource for items manufactured from cellulose of lower quality (3). The resource can be reused up to seven cycles for production of the cellulose items of the lowest quality (for example, pallets or heat insulation materials). While enterprises involved in stages (2) and (3) in accordance with Russian standards belong to micro and small businesses, those involved in stages (1) and (3) are medium-sized businesses.

Application of the LCA method implies calculation of externality values separately from direct costs. Thus, when determining economic efficiency of the circular economy approach in the industrial sector of the cellulosic items production, we analyze changes occurring in direct costs (raw material costs, energy sources) due to the use of waste paper resulting in prime cost reduction, as well as co-benefits obtained due to the following positive externalities:

- Significant reduction of environmental pollution (water, air, and soil) due to the decrease in the volume of products manufactured from virgin raw materials.
- Reduction of waste burial expenses (waste paper incineration or storage at landfills).
- Reduced consumption of natural resources (in case of waste paper treatment it is industrial wood).

The study of MSW paper fraction is determined by the availability of a quite developed (compared to others) collection and recycling network, as well as by its significant share in the MSW morphological composition (See Figure 3).



**Figure 3.** MSW morphological composition, Yekaterinburg, % per unit of volume. \* See Reference [44]; \*\* Data obtained from the Integrated Strategy to Manage Wastes, including MSW, in Sverdlovskaya Oblast.

As per Reference [44], waste in Sverdlovskaya Oblast is mostly composed of paper and food organics. Unfortunately, the technology of shredding and discharge of edible waste through municipal water supply sources with further removal by hydrobionts is hardly applied. The presence of a high volume of non-organic components (more than 70%) in municipal waste is typical of cities with rather high social levels and is also indicative of the potential of their recycling [45].

## 4. Results

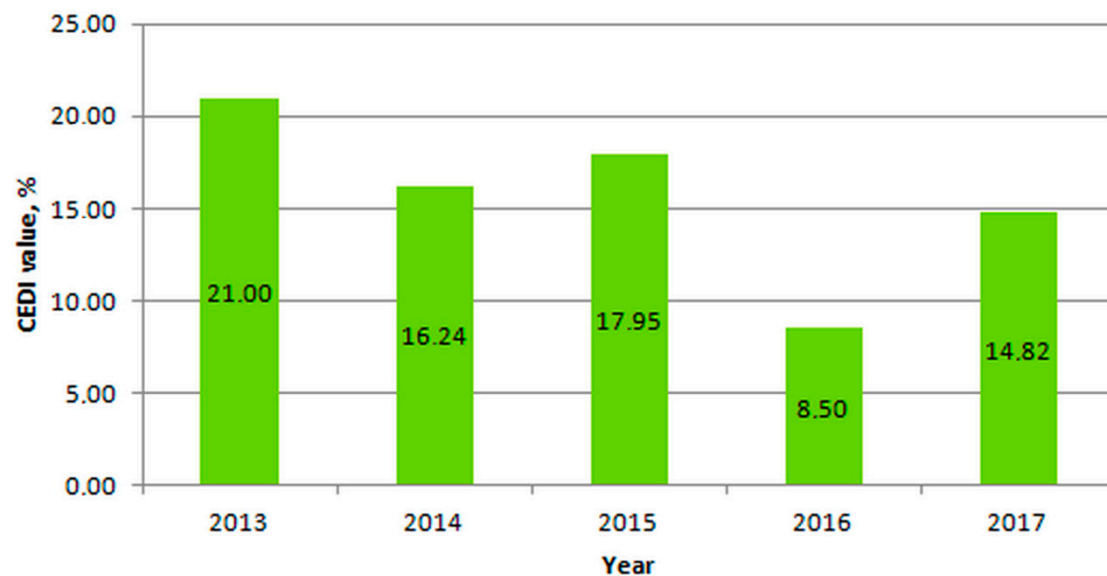
### 4.1. Circular Economy Development Index Evaluation in Sverdlovskaya Oblast

The calculations show that the circular economy development level in the context of MSW management evaluated through the CEDI in 2017 in Sverdlovskaya Oblast was

$$\text{CEDI}_{2017} = (209.6 \times 1 + 0 \times 0.47) \times 100\% / 1414.0 = 14.82\%. \quad (2)$$

The CEDI values for the region were calculated for the period from 2013 to 2017 (See Figure 4).

As Figure 4 shows, the results obtained on the basis of the data from statistical state reporting demonstrate irregularities in the recycling levels which can be attributed either to inaccuracies in the data provided by the State Agency or to a current unstable situation, both reasons being in need of adjustment. Both above mentioned reasons can coexist. It must be stated that Sverdlovskaya Oblast had a rather low circular economy development index that was equal to about 16% on average with its lowest value of 8.5% in 2016.



**Figure 4.** Circular Economy Development Index (CEDI) dynamics in Sverdlovskaya Oblast during the period from 2013 to 2017.

#### 4.2. Calculation of Economic Benefit of A Paper Mill

The LCA-based approach allowed us to compare the economic benefits of the use of secondary resources obtained by companies of different sizes and activity profiles (e.g., manufacturers to waste processors), being participants of one and the same resource cycle and drawing certain conclusions.

The calculations showed that the use of the secondary raw materials at a paper mill (paper and cardboard production) reduces material (direct) costs to more than 56% (See Tables 6 and 7). This is attributed to a lower price for waste paper compared to virgin raw materials (by 2.5 times), and significantly reduced water and energy consumption (35 and 40%, respectively). With industry average 35.0% cost-efficiency, profitability of such production increases notably.

In Russia, rated environmental pollution payments are part of prime cost of finished products; therefore, they influence the profitability of the economic activity. Thus, direct cost savings for the production of items manufactured from secondary raw materials (i.e., waste paper) and savings gained due to the decrease in environmental pollution allow manufacturers to reduce the prime cost of their products at production stages (1) and (3).

In contrast to manufacturers, the companies responsible for paper waste treatment, being usually micro and small enterprises, have a rather low-cost efficiency. As per our calculations, their expenses can reach more than 95% of profit. This is attributed to the high costs of raw material transportation and waste paper pressing equipment costs. However, the profitability of these companies can increase due to the decrease in specific consumption of fixed costs resulting from consolidation (for example, partnerships). The Ural Union of Waste Processors established in 2015 is a good example. It increased its profitability by almost 2.5 times over the last two years. Besides, the MSW treatment tariff was introduced in 2019, which will enable these companies to increase their efficiency.

**Table 6.** Comparison of material costs for production of one ton of paper with the use of different types of raw materials.

Costs	Cellulose			Waste paper		
	Quantity	Price	Sum, RUB	Quantity	Price	Sum, RUB
Semi-finished products, tons/ tons	0.752	19,216.2	14,450.58	0.752	8000	6016
Fresh water, m <sup>3</sup> /t	11.00	13.78	151.58	7.15	13.78	98.53
Electric power, kWh/t	400	3.42	1368	240	3.42	820.80
Water discharge, m <sup>3</sup> /t	11.00	9.18	100.98	7.15	9.18	65.63
Total			16,071.14			7000.97

Source: Consumption indices [46]; market prices in rubles (rub) for materials and energy sources in 2018.

**Table 7.** Comparison of material costs for production of one ton of cardboard with the use of different types of raw materials.

Costs	Cellulose			Waste paper		
	Quantity	Price	Sum, RUB	Quantity	Price	Sum, RUB
Semi-finished products, thousand tons	0.921	19,216.2	17,698.12	0.921	8000	7368
Fresh water, m <sup>3</sup> /t	10.00	13.78	137.8	6.50	13.78	89.57
Electric power, kWh/t	435.00	3.42	1487.70	261	3.42	892.62
Water discharge, m <sup>3</sup> /t	10.00	9.18	91.80	6.50	9.18	59.67
Total			19,415.42			8409.86

Source: Consumption indices [46]; market prices in rub for materials and energy sources in 2018.

Other co-benefits from positive externalities were determined by forward calculation with the prices in 2018 and were equal to about 10,000 rubles per one ton of products:

- 2000 rubles/t—when incineration of waste paper is replaced with its recycling.
- About 6000–8000 rubles—due to reduced resource consumption (assuming that 1 ton of paper requires 3–4 m<sup>3</sup> of wood with an average market price of timber equal to about 2000 rub/m<sup>3</sup>).

As it can be seen, co-benefits outperform specific economic benefit from prime cost reduction. At the same time, the value of the environmental fee is significantly lower the savings resulting from preservation of the virgin resource and reduction of waste burial expenses [47]. It can internalize external factors into the market prices of the paper industry products only if there is upward adjustment.

It should be noted that such external expenses can be partially (due to lower environmental pollution payments) considered in the activity of the manufacturers producing items out of virgin and secondary resources (stages (1) and (3)) and not influence performance of the companies that are responsible for auxiliary functions (waste collection, transportation, sorting) (stage (2)). In case of such a prudent approach towards internalization of the consequences of environmental management into economic activity, social benefits can obtain expression in monetary terms and influence the activity of an economic entity.

Besides environmental pollution payments, there is also the environmental fee in Russia that must be paid by the enterprises manufacturing items subject to recycling but not recycling them themselves. For the paper industry, the regulatory standard stipulates recycling for 2018 as 25% of the physical volume of manufactured products, while the rate of fee is 2378 rub/per one ton of waste [48,49].

Generally, potential profits from the waste paper recycling in the current collection system with due regard to target recycling volume within 60% of the produced wastes can reach in Sverdlovskaya Oblast about 2.7 b rub/year exclusive of externalities (as per the calculations of the authors [50]).

Today revenue loss in this industry is huge, as only one-third of the potential volume of waste paper is collected.

## 5. Discussion

There is a low level of development of the circular economy in the Russian Federation with insignificant deviations in certain regions. The development of the circular economy in Sverdlovskaya Oblast showed fluctuations in values rather than gradual growth (within the period from 2013 to 2017 from 8.5% to 21%), showing the instability of the situation and little opportunity to use state statistics. When we compared the data with other countries, we obtained the following results: while generally throughout Russia in 2015 the CEDI was equal to 6%, in Germany, it reached 55% [19]. The high index value in Germany, like in many other EU countries, was achieved due to the systematic implementation of waste management policies. For the implementation of this policy and elaboration of the regulatory frameworks, the EU established a clear hierarchy of waste management methods that sets the priorities for the development of the resource circularity. The waste management system cannot be based only on waste management at the recovery stage. It should use more integrated approaches in addressing this issue [51–53]. Russia lacks such a hierarchy at the moment.

The low level of the circular economy development in Russia can be attributed to a number of reasons. It has already been noted that the economic efficiency of economic activity may be considered to be the main incentive for implementation of the circular economy in the Russian Federation at the present moment. The calculations performed for a paper mill showed that only direct economic benefit from the use of secondary raw materials can be quite significant (the cost of production of cardboard and paper was reduced by 2.5 times). However, in Russia there is no intensive implementation of the circularity principles in this and other industries capable of cost-efficient operation with the involvement of secondary raw materials. The analysis of the sources, questionnaires for the entrepreneurs and public opinion polls indicate that state management failures are the main reasons for it.

First of all, this includes legal requirements with regard to waste recovery rate settings. In Russia, waste recovery targets established in 2015 (as per Federal Law No. 458) are substantially lower than those applied in the EU. Justification of the waste recovery standards and the procedure of their implementation into economic activities are also far from being well developed. For example, the regulatory standards originally stipulated for the recycling of paper, rubber, and plastic items was 80%, and for machines and electrical equipment it was 50%. However, numerous claims from manufacturers and importers led to the reduction of this level. In 2018, the rate for paper and cardboard was 25%, and in 2019—35%; for tires and the outer casing of a tire—20 and 25%, respectively; for plastic packaging—10 and 15%, and for hollow glass—15 and 20%. The rates for waste electronic equipment were introduced only in 2017 at the level of 5%. It remained the same in 2018, but in 2019 it was increased to 10%.

Secondly, financial state support to the waste processing enterprises is not sufficiently developed legislatively. For example, benefits under Article 24 of Federal Law Concerning production and consumer wastes in the Russian Federation include tax privileges, reduced environmental pollution payments, a decreasing coefficient for recycling standard for the goods manufactured from secondary raw materials, and state budget support when handling the goods subject to recycling. However, subordinate legislation lacks further details for these regulations, therefore they cannot be applied in practice.

For example, highly profitable enterprises in the paper industry do not strive to increase the volume of secondary resources they use despite a significant reduction in the prime cost of products. This requires additional expenses for waste collection management. The volume and quality of the secondary raw materials delivered by the suppliers are not sufficient. In 2014, upon adoption of amendments for the law concerning production and consumer wastes (Federal Law No.458), investors started to pile into the construction of waste paper mills, but now freeze their projects as the law does not work and no one gives waste paper to recycling. The problem of the raw material shortage can be

solved through the development of sorting facilities and through provision of incentives for separate MSW collection. In conditions of prosperity of small- and medium-sized enterprises being principal entities in respect of waste management, such investments could be justified, but there are practically no such enterprises in the Russian Federation at the moment [54]. Therefore, recycling exists within the limits prescribed by law. For example, the volume of waste paper use throughout the region (16%) is relatively close to the recycling rate (25%).

At the same time, foreign experience shows that particular attention from the state and international bodies, as well as substantial benefits that accompany the implementation of circular economy principles help many companies introduce respective business models into their activity [6,7].

The third possible reason is the lack of necessary level of internalization of such externalities, such as reduced waste volume, reduced environmental damage, and virgin resource consumption having social value in the form of environmental taxes or fees. State policy tends to increase environmental responsibility of economic entities: the best available technologies are being introduced by law, and coefficients to the rates of pollution payments are being increased. Yet at the moment, economic management levers do not significantly influence the situation like they do in developed countries [55].

Specifically, the environmental fee simply outlines actual externalities as a mere formality rather than showing the actual expenses for waste recycling. Thus, it cannot internalize them into market prices. The same situation was observed with the environmental pollution payments that are far lower compared to environmental damage defined in the state methodology. Thus, it can be said that the introduced requirements are a mere formality, which does not ease the situation and does not lead to the increase in the waste recycling volume and decrease in environmental pollution.

Irregularity of waste fraction recycling is also an important point (the fifth reason). The authors' research of the situation pertaining to the collection of different MSW fractions showed that some of them are more preferable, which contributes to the development of the network for their collection. This is attributed to the availability of treatment technologies with higher profitability as in case of paper and plastic wastes, or to regional traditions as in case of scrap metal. However, the preference of processing enterprises for specific types of waste over the rest leads to selective recovery. Disposal of "unpopular" wastes and lowering their accumulation require participation of the state.

Separate waste collection with further recycling is likely to be introduced in Sverdlovskaya Oblast in the future. To engage new entities in this activity, it is necessary to create favorable conditions for business development. A proper tariff system can lead to positive results, both environmental and economic [56].

Introduction of ceiling tariffs for implementation of governed activities pertaining to MSW management in 2019 can be a good incentive. However, the legislation does not only fail to provide for, but even abolished an MSW recovery tariff that had existed before 2018. These create conditions which are leading to a situation where a regional operator will get more benefits collecting wastes at landfills rather than recycling them.

Positive trends have recently been noted. Ongoing reforms in waste management have laid the foundation for the development of schemes for processing and recycling of wastes unsuitable for further use and provision of the industry with high-tech modern equipment. New priorities in the development of the industry and changes in legislation are likely to improve the situation in the near future, provided that the state, business, and the population work together.

## 6. Conclusions

The current trend of resource recycling serving as a basis for the circular economy is not accidental. It is dictated by economic, environmental, and social considerations in conditions of a growing volume of consumption and shortage of resources, as well as environmental degradation.

The research conducted to identify the main problems and obstacles hindering the CE development in respect to waste management over the past five years has shown that a linear economic model



prevails in Russia. Thus, the calculation of the CE development index in Sverdlovskaya Oblast showed that the CE development level in the region lags behind Europe and was equal to 16% on average, while the volume of MSW recovery and neutralization was 15.5% (being mainly paper and plastic waste). To achieve regional target figures, the regional recovery volume should be increased by almost four times by 2030.

Evaluation of the economic efficiency in respect to the recycling of the addressed MSW paper fraction showed the economic feasibility of the use of secondary raw materials both for manufacturers (through reducing direct current costs by saving material and energy resources) and for society (due to the externalities related to preservation of virgin resources and reduction of ecological burden).

The research showed the lack of prepared secondary resources, i.e., MSW collection and sorting, to be the weakest link in the resource cycles. In order to create optimal conditions for processing, recovery, and minimization of the amount of waste unsuitable for further use, state agencies should improve the legal, economic, and political management tools aimed at the provision of the attractive conditions for the development of micro-, small-, and medium-sized enterprises, which will result in the emergence of new waste treatment entities and stimulate the development and implementation of innovative technologies.

Further research can be directed towards a more in-depth study of the specificities of the implementation of the waste management policies in different regions of Russia and the identification of the most advanced, in terms of the CE principles implementation, management methods, aimed at introducing advanced waste treatment ways and attracting business and population to a more effective solution of problems hindering the CE development. This will make it possible to elaborate more specific recommendations for the organization of business models within the framework of the CE development with due regard to Russian specificities.

Besides, further study of the Russian specificities of determining the efficiency of the externalities and their internalization in the cost of goods will strengthen the position of the circular economy in Russia.

The research and analysis of the obtained results were limited by the insufficient data on the economic activity of the waste processing companies, as well as imperfection of statistical information that depend on regularly changing data calculation methods. The latter restriction is a sign of the reformation period, and thus is of a temporary nature.

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